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MILITARY UTILITY OF HEL FIGHTER

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14. ABSTRACT
This paper gives a very brief overview of the Directed Energy Worth Analysis and Vehicle Evaluation program (DEWAVE), a military utility analysis of a tactical fighter equipped with a high-energy laser. This paper describes the objectives of the effort and discusses, at a very top level only, the analyses and results.

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One of the principal objectives of technology development within the armed services is to enable advanced capabilities for the warfighter. High-energy lasers (HEL) certainly fall in this category. It is believed by many that HEL will provide revolutionary capabilities. Laser characteristics such as speed-of-light delivery, insensitivity to the effects of gravity, extreme precision, tailorable effects, deep magazine, and low cost engagements are generally thought will translate into compelling military benefits. The air vehicles directorate of the Air Force Research Laboratory (AFRL/VA) has sponsored a study to investigate the military utility of a fighter-based laser weapon under an effort called Directed Energy Worth Analysis and Vehicle Evaluations (DE WAVE). This paper provides an overview of the results of this study.

The primary reasons for performing military utility studies are 1) to demonstrate and quantify military benefits (e.g., lethality, survivability, affordability, supportability) 2) to determine mission requirements for the proposed capability, which in turn are used to derive system requirements and allocate subsystem and component requirements (see Figure 1), and 3) to evaluate design options, including the value of advanced technologies.

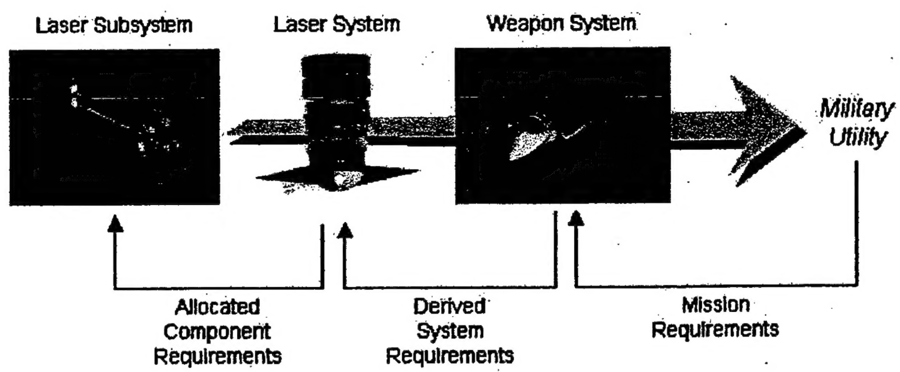

Figure 1. Military utility studies provide justification for enabling technology development, are used to derive mission requirements, and offer a mechanism for assessing the value of various design options, such as advanced technologies.

The goal of DE WAVE was to go at least a level deeper in technical fidelity than previous fighter-based laser weapon studies. That said, we are still concentrating on basic issues such as what can a laser weapon do against military targets and is this something useful to operational commanders, can HEL be effectively employed (survivability being a key issue), and what are the operational benefits of HEL-equipped fighters.

The DE WAVE study was performed in conjunction with an industry-funded laser weapon system design and integration study (called Laser Strike Fighter) for the express purpose of anchoring the benefits assessment to a specific and well-defined system concept. Details of

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the system and its integration into a fighter are proprietary and will not be discussed in this paper (they are available upon request). The baseline HEL system configuration resulting from this study consists of 100 kW solid state laser with 1.2 times diffraction limited beam quality, 30 cm aperture, one micro-radian line-of-sight stabilization, and a deployable beam director on the bottom of the fuselage with –10° to –90° in elevation coverage and ±165° in azimuth coverage.

Targets

A majority of airborne and ground-based military targets, including IR and RF antiaircraft missile threats, are vulnerable to lasers. It must be noted, however, that a laser weapon attack is fundamentally different than an attack by conventional high explosive weapons. Because lasers cause very localized damage what is really being attacked are target components (e.g., critical electronics located beneath the skin, sensors, load bearing structure, fuel tank). Whereas conventional weapons typically destroy its targets, laser weapons will usually produce far less destructive, but still desirable, effects (e.g., functional kill, mobility kill).

An important attribute of the Laser Strike Fighter concept is that it can also carry and employ the normal complement of conventional weapons. Laser weapons offer a new suite of capabilities, but it is important not to take a step backward from existing capabilities. The benefits of laser weapons are especially compelling when combined with conventional weapons.

The final point to note is that most targets will have several components that are susceptible to lasers, each component having its own associated vulnerability requirements (fluence, spot size, minimum irradiance). In the following section we will present estimates of laser weapon performance versus target hardness (i.e., required fluence to cause desired response). It will be shown that the 100 kW baseline concept has robust performance against most targets.

Laser Weapon Performance

Range performance was estimated for the baseline HEL configuration using an illumination time of 5 sec. In order to estimate the range variations that are normally encountered with electro-optical systems in day-to-day operations we used atmospheric transmission values corresponding to 5 and 23 km visibility, representing bad day and good day conditions, respectively. We also used high and low estimates for residual corrected Strehl due to laser propagation through the platform flowfield. We then calculated the best case and worst-case range performance for targets with vulnerability requirements spanning from 250 J/cm^2 up to 15,000 J/cm^2 (see Figure 2). These range predictions indicate that our baseline system concept has robust performance (i.e., employable under good and bad conditions) against a majority of susceptible targets. Even under poor visibility conditions and under engagement geometries that are not ideal for propagation through the platform flowfield the baseline system is sufficient to meet minimum standoff range requirements (around 5 km, determined based on stringent survivability requirements).

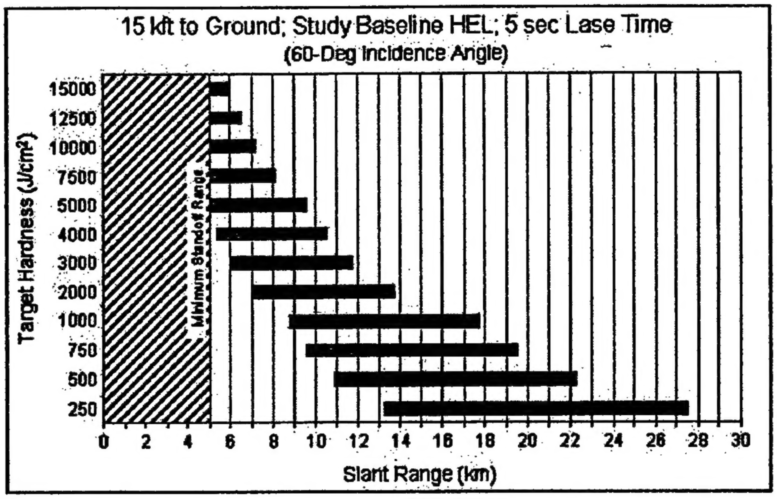

Figure 2. Lethal range versus target hardness. Range bar variations span from bad (left) to good (right) conditions: good conditions are defined as 23 km atmospheric visibility & forward aspect engagement; bad conditions as 5 km atmospheric visibility & high off-boresight engagement.

Likewise, we analyzed range performance against IR and RF antiaircraft missile threats. Here too we looked at a range of conditions such as closing geometries up to 2000 m/s and a range of atmospheric conditions. Range predictions indicate that the baseline 100 kW capability will provide robust performance against a majority of missile threats, including RF missiles. It is important to note, however, that all the analyses assume a clear line-of-sight to the target.

Mission Effectiveness

The Brawler air combat simulation was used to evaluate mission effectiveness for cruise missile defense (CMD) and defensive counterair (DCA) missions. For each mission we evaluated normal and stressing scenarios of blue versus red. For CMD we looked at 4 blue fighters versus 13 incoming cruise missiles (4v13) as well as 3v13. For DCA we evaluated 4 blue fighters versus 4 red fighter escorts and 2 red bombers (4v6) as well as 2v6.

Results of these studies clearly demonstrate three benefits when HEL weapons are employed together with conventional weapons against airborne targets: 1) increased lethality, enhanced survivability, and reduced missile usage, which improves post-engagement capabilities. These results were consistent over a wide variety of conditions. Given the fact that attackable ground targets (target components) have about the same hardness as airborne targets, we would expect similar results for air-to-ground scenarios.

Sensitivity trades were performed to look at the effect of varying laser power, HEL field-of-regard, targeting doctrine, illumination time, radar cross section of the HEL beam director, aircraft signature, laser weapon probability of kill (Pk), among others. The objectives of the sensitivity trades are twofold. One, they help to identify trends in order to assess whether laser weapons provide robust performance over a large variety of conditions and operations. Second, the sensitivity trades help to optimize HEL effectiveness. For example, studies indicate that increasing the maximum upward elevation coverage from –10 deg to 0 deg significantly improves mission effectiveness and survivability over and above what's already been demonstrated with the baseline system.

Role of Laser Weapons on Fighters

One of the big questions that needs to be addressed is what is the role of laser weapons on fighters. A quantitative answer to this question will be difficult to obtain. Current simulation tools were not designed to capture the benefits for many of the things that laser weapons are good at (non-destructive effects, for instance). From studies done to-date it is clear that laser weapons offer a lot of capabilities that are complementary to conventional high explosive weapons. They are effective for both offensive and defensive operations, have a very deep magazine, are invisible to the unaided eye and silent, are insensitive to any form of electronic jamming, offer high off-boresight operations with fast response time, are extremely precise, and have limited collateral damage. Taken as a whole, HEL capabilities will substantially increase the overall operational flexibility and adaptability of fighters (see Figure 3).

- Rapidly Deployable, Real Time Multi-Role
- Deep Magazine
- Force-Multiplier
- Precision Strike With Low Collateral Damage
- Destructive & Non-Destructive Effects
- Threat Independent Countermeasure
- Covert

Figure 3. HEL offers a new suite of capabilities — improves fighter lethality and survivability, and substantially enhances overall operational flexibility.

Conclusions

This study has clearly demonstrated that laser weapons can be effectively employed against aircraft, cruise missiles, and antiaircraft missile threats from a fighter. For the air combat scenarios investigated, HEL weapons improved mission effectiveness and survivability, and reduced missile usage (improved post-engagement capability), in stressing situations. Based on the similarity in target vulnerability levels between airborne and ground targets, we expect comparable results for air-to-ground missions (note, ground targets are usually disabled by laser attack, they are generally not destroyed).

We have also shown that a 100 kW laser weapon will provide short to medium-range performance against a wide variety of air and ground targets, and that its range performance is acceptable even under poor atmospheric and engagement conditions.

As significant as these results are, perhaps the most important contribution that HEL will offer is in the area of *operational flexibility*. The inherent attributes of laser weapons translate into a unique set of capabilities that are complementary to conventional weapons. There are many aspects of laser weapons that won't be fully understood or appreciated until they are deployed on fighters and used in real-life situations. However, it is clear that laser weapon capabilities can enhance the responsiveness and flexibility of fighter operations.